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Round-Table Discussions on the Development
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Gafsa, Tunisia, 18 - 22 November 1985

THE ROLE OF IMPURITIES IN DETERMINING THE PERFORMANCE OF PHOSPHORIC ACID MANUFACTURE BY THE HEMIHYDRATE PROCESS*

Prepared by

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SUMMARY

The mining of phosphate rock, and the beneficiation routes used, both affect the concentration of impurities present, and these in turn directly influence the processing characteristics of the rock.

In determining the optimum mining and beneficiation route consideration should be given to the effects these routes have on impurity levels, in addition to the more usual factors, such as P_2O_5 enrichment.

Due to the complex nature of the chemistry involved, it is not possible to quantify the effects of impurities without thoroughly testing a rock, using techniques which model the process route to be used.

This paper outlines the type of evaluation techniques required and considers the effects of impurities on the performance of the energy saving Hemihydrate process route.

Introduction

The primary component of a mined phosphate rock is Fluorapatite which occurs in nature in association with igneous rocks, or more commonly as phosphorites combined with sedimentary rocks. Other forms of apatite such as Hydroxyapatite and Chlorapatite are also found but these are less common, particularly the latter.

The mining methods used are largely dependent on the depth and nature of the overburden. These may involve open cast methods using scrapers or drag lines, or it may be necessary to apply underground shaft and tunnel methods. The raw rock generally requires beneficiating before it is suitable for the manufacture of phosphoric acid. The methods employed generally depend on the nature of the associated impurities and minerals. The simplest method involves crushing and screening operations followed by density separations, using for example, hydrocyclones. The desired degree of upgrading cannot always be achieved by this method and more complicated and expensive procedures, such as flotation and calcination, have to be employed.

Phosphate rocks contain a wide range of impurities, none of which are completely removed by the beneficiation process. The need to beneficiate and the choice of method should not be dictated solely by the requirement to maximise P_2O_5 concentration. The removal of impurities can increase or reduce the performance of a phosphate rock when used for phosphoric acid manufacture. This is true for both Dihydrate and Hemihydrate processes and implies that the mining and beneficiation operations should ideally take into account the implications on processing characteristics if a technical overall optimum is to be achieved.

The assessment of phosphate rocks using laboratory and pilot plant techniques is an important link between the producer of a rock and the potential user.

It provides essential data which can be taken into account when optimising beneficiation procedures and give guidelines to the suitability of a process route and the choice of operating condition.

In developing both Dihydrate and Hemihydrate phosphoric acid processes, Norsk Hydro Fertilizers UK, has extensive experience in the field of rock testing which covers a period of over 27 years. This paper outlines the more important aspects of the test procedures used and the effects of impurities on the performance of phosphoric acid manufacture by the Hemihydrate route.

Impurities Present in Phosphate Rocks

Phosphate rocks are usually found in association with silica minerals such as quartz, clays, serpentine, pyroxenes and micas. Carbonate minerals such as calcite or dolomite are also common and the choice of the beneficiation process is usually dictated by the requirement to remove these major impurities.

The remaining impurities are present in minor and in trace amounts. Many of these can affect processing characteristics and need to be taken into account when evaluating the beneficiation process.

Table 1 gives the range of impurities normally present in phosphate rocks together with the range of concentrations which can be encountered. It is important to bear in mind that of the impurities which normally affect processing performance, the relative effects, will not only be influenced by the amounts of impurities present, but also on the reactivity of the minerals which provide these impurities. The impurities produce charged ions which compete to attract other ions and produce compounds which can precipitate or be evolved in the off gases. Which type of "ion trapping" predominates will depend on the rates of formation of the individual ions as well as the concentrations produced. This kinetic effect is the main reason why it is very difficult to predict the performance of a phosphate rock when used to manufacture phosphoric acid. With experience, general behaviour patterns can be predicted, but to quantify

sufficiently for plant design, or evaluate the economic implications of changing rock sources, it is necessary to determine performance parameters experimentally.

The effect of Impurities on Hemihydrate Process Performance

In broad terms the effects of impurities are similar for both the Hemihydrate and Dihydrate processes. However, there are important differences which are mainly due to the reaction conditions used when producing hemihydrate.

A summary of the most important effects are as follows:

Carbonates

Calcite or dolomite are the usual minerals which provide carbonate. During acidulation of the rock the carbonate will decompose producing carbon dioxide which is evolved in the off gases. In the Hemihydrate process the acid P_2O_5 concentration can be controlled between 40% and 50% which gives the acid a higher density and viscosity compared to the acid produced by a Dihydrate process. The increase in viscosity causes more entrainment of the CO_2 and the acid in the reactor becomes "gassed". Defoamer can be used as a means of control. Mechanical foam breakers are less effective unless these produce a large turn-over of slurry surface. It is important to minimise the gassing level as this eventually has an adverse effect on hemihydrate crystal growth. Gassing levels of up to 20% are usually not harmful. The other effect caused by entrainment of CO_2 is that it causes a reduction in reactor operating levels during short shutdowns of the plant. On start-up this change in level has to be considered if good sulphate control is to be maintained. Organic matter present in rock can also reduce the rate of de-entrainment and affect the effectiveness of defoamers. This effect has sometimes been noticed with calcined rocks, rarely with others. If a significant proportion of the carbonate is present in the apatite structure, as in Francolite, then its decomposition can cause disintigration of the rock grains and increase the reaction rate.

Silica

This is one of the most common impurities present in rocks and is usually present in the form of quartz or clays with sometimes minor quantities of micas, pyroxenes and serpentines. Quartz reacts slowly in phosphoric acid containing fluorine, whereas silica in clays react readily. The availability of reactive silica determines the extent of fluorine evolution and the availability of fluoride ions to trap metallic cations such as calcium and aluminium. The ionic reaction involving aluminium affects hemihydrate crystal properties and filterability. In rare cases where there is a deficiency of silica the concentration of fluoride can increase which can produce increased corrosion rates in a phosphoric acid plant. Some low P_2O_5 grade rocks contain high levels of silica, most of which is relatively unreactive. In these cases the waste silica can constitute a significant proportion of the solids which are filtered and in consequence can affect filterability. For example, if the silica is coarse then it can act as a filter aid and improve filtration. If as a result of beneficiation, or grinding at the user plant, the silica is in a finely divided state, then this can blind the filter cake and reduce filterability.

Fluorine

All phosphate rocks apart from chlorapatites contain fluorine within the apatitic structure. It plays a significant part in the chemistry of phosphoric acid manufacture, both Hemihydrate and Dihydrate. In the Hemihydrate process the higher reaction temperature and P_2O_5 concentration produces more evolution of the fluorine as SiF_4 from the reaction system compared to the Dihydrate process. The higher reaction temperature also favours the decomposition of the SiF_6^{--} ion to F^- which in turn reacts with calcium ions and aluminium ions to produce compounds or complexes which are removed with the hemihydrate. As already mentioned the aluminium fluoride complex ion can influence the crystal properties of the hemihydrate and its filterability. Due to the complexing of part of the aluminium the Hemihydrate process produces an acid which has a lower aluminium concentration compared to the Dihydrate process from a given rock. Fluorine

together with silica are responsible for the formation of fluorsilicate scales in both processes.

Metallic Impurities

Cationic impurities can affect processing performance in several ways. The influence of aluminium on hemihydrate filterability has already been mentioned. Iron and Magnesium have little effect on crystal properties, but they can affect acid viscosity which in turn influences filtration rates. Complex compounds can also be produced which precipitate slowly and form sludge in acid storage tanks and occasionally even in the filter return acid tanks. Blinding of filter cakes and cloths also occurs but only in rare cases where impure rocks are processed containing high concentrations of Magnesium, Iron and Aluminium.

Alkali metals combine with SiF_6^{--} ions to produce silicofluorides which can form scale. This occurs in both Dihydrate and Hemihydrate processes but there are important differences in behaviour. Due to the higher acid P_2O_5 concentration in the Hemihydrate process the solubility of Na_2SiF_6 is very low and unlike the Dihydrate process this eliminates any tendency for scale to occur in reaction vessels and pipework handling slurry. On the filter the higher acid P_2O_5 concentration increases the driving force for silicofluoride scaling and the degree of scaling depends on the concentrations of alkali metals present in the rock.

Test Procedures

The test methods used at Levington vary in complexity from analysis and simple laboratory tests to continuous pilot plant operation for the production of phosphoric acid. The scope of the test work will depend on the state of the project, which may be preliminary, intermediate or advanced. For example, in the case where a new rock deposit is being evaluated, a large number of samples may be involved, originating from core samples taken from different parts of the deposit, or produced by different beneficiation routes. In this case preliminary laboratory tests would be the quickest and most cost effective approach. Where the rock composition is defined, and the mining and beneficiation routes finalised,

it is necessary to quantify the important processing parameters which affect the economics of phosphoric acid manufacture by a full pilot plant evaluation. Other examples fall between these two extremes and are planned accordingly to provide the required information with the minimum of cost.

Detailed descriptions of the main test procedures used have already been published (1, 2) and it is only possible within the scope of this paper to give a brief outline of the most important techniques.

The selected test procedure will involve some or all of the following tests:

Sampling

A representative sample must be obtained before any test work is carried out. Normally the rock is shipped in several containers and these should be emptied and the whole consignment mixed until homogeneous.

Physical and Chemical Properties

A sample of the mixed rock is analysed by X-ray diffraction, atomic absorption and chemical methods for all compounds likely to influence its behaviour. Particle size and distribution are important since these factors can affect the rate of reaction, which in turn can influence reaction control, P_2O_5 efficiency and filterability. A complete sieve analysis is carried out on all samples which have been prepared for specific tests.

Reactivity

The reactivity of a rock can be determined by a batch or a continuous test. The batch technique is a simple dissolution test using phosphoric acid and sulphuric acids and rocks having a constant size fraction. A continuous test can be used to determine the level of unreacted rock directly for a given set of operating conditions.

Foaming

To assess the degree of foaming which a rock may produce, a standard sieve fraction is acidulated with phosphoric acid. The height of foam produced is

plotted against time and the area under the curve is calculated. This area is termed the "Foam Stability Index" and is compared with values obtained from other rocks whose foaming characteristics on a full scale plant are known.

Crystallisation Tests

These are laboratory tests and involve continuous acidulation of phosphate rock in two or more stirred tank reaction vessels. The laboratory unit provides comparative data on crystal properties and filtration rate and its main purpose is to obtain an indication of expected performance and to screen rock samples if several are involved. This type of unit is also used for development work and in particular in the basic study of the effects of impurities on crystal properties.

Pilot Plant Tests

Although laboratory tests give valuable guidelines on raw material selection and performance, the data produced are largely comparative and must be quantified on a pilot plant. In any pilot plant trial the operation is continuous over a period of at least 100 hours. The reactor residence times and operating conditions are the same as would be used on a full scale plant and no evaluation of results is carried out until equilibrium has been reached.

Pilot plants can be used to compare the performance of rocks under a given set of operating conditions. They can also be used to optimise operating conditions for a given rock.

The following illustrates the type of information provided by a typical pilot plant trial:

(a) Magnitude and type of P_2O_5 loss. P_2O_5 efficiency.

(b) Expected filter loading using different types of filter.

(c) Sulphuric acid, defoamer and other chemical additive consumptions.

(d) Compositions of rock, acid and hemihydrate and expected proportionation of impurities.

(e) Process Heat and Mass Balance.

Post Pilot Plant Tests

Following the pilot plant investigation further tests are frequently carried out to provide additional data for plant design and/or the manufacture of phosphatic intermediates. These could involve:

Settling Tests

Any solid which is precipitated with time from the product acid is quantified and identified.

Corrosion Tests

Phosphoric acid produced from different rocks can often produce widely different corrosion rates when in contact with alloy steels. The impurities which have the greatest effect on corrosion are Chloride, Fluoride and reducing agents such as Sulphides. Static corrosion tests are carried out using pilot plant acid and standard alloys commonly used to fabricate phosphoric acid plants.

Physical Properties

Measurements of density, viscosity or vapour pressure are made on the product acid to provide design data.

Preparation of Ammonium Phosphates and Triple Superphosphate

These intermediates are prepared in the laboratory to provide product compositions.

References

1. Robinson N. "The Assessment of Phosphate Rocks for Phosphoric Acid and Ammonium Phosphate Manufacture". Phosphorous and Potassium No. 57, January/February 1972.

2. Robinson N. "Laboratory and Pilot Plant Assessment of Phosphate Rocks for Phosphoric Acid and Ammonium Phosphate Manufacture". I.S.M.A./A.N.D.A. Technical Conference Sao Paulo, 1972.

Table 1 Typical Impurities Present in Phosphate Rocks (% w/w)

Impurity	Range	Impurity	Range
CaO	22-55	SO_4	0-4
SiO_2	0.1-35	CO_2	0.05-8
Fe_2O_3	0.1-3	Organic	0-0.6
Al_2O_3	0.1-3	SrO	0-2
MgO	0.1-2	U_3O_8	0.0008-0.02
Na_2O	0.03-1.5		
K_2O	0.01-0.3		
Cl	0.003-0.15		

In addition to the above a large number of trace elements occur including Cu, As, Cr, Cd, Rare Earths, Ni, Hg etc.

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MAXIMIZING THE SHARE OF DOMESTIC RAW MATERIALS IN DEVELOPING THE PHOSPHATE FERTILIZER INDUSTRY*

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Summary

Phosphate rock accounts typically only for 10 to 50 per cent of the total raw material costs of compound and phosphate fertilizers. The rest is due to sulphur, nitrogen and potash.

As the international raw material prices often fluctuate quite independently from the final product prices, it is natural for any phosphate fertilizer producer to try to avoid too heavy dependence on imported raw materials. In the opposite case, an increasing foreign currency expenditure might jeopardize the total economy of a phosphate fertilizer project.

The raw material cost structure varies widely between different products and processes. In this paper the primary raw material costs of the following products are broken down:

- TSP
- DAP
- NPK

Moreover, regarding the manufacture of NPK fertilizers, the following three processes are compared:

- nitrophosphate NPK process
- urea-based NPK process
- phosphonitric NPK process.

The raw materials of compound and phosphate fertilizer production are very seldom found all in one country but, fortunately enough, the variety of fertilizer processes available today enables the maximization of the share of domestic raw materials in each particular case.

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1 Introduction

2 Basis of Process Comparison

3 Cost Calculations

4 Maximizing Domestic Share

5 Special Case:
Countries with Domestic Phosphate and Potash (P+K regions)

6 Conclusions

1 INTRODUCTION

Phosphate rock accounts typically only for 10 to 50 per cent of the total raw material costs of compound and phosphate fertilizers. The rest is due to sulphur, nitrogen (mostly ammonia) and potash (potassium chloride or potassium sulphate).

As the international raw material prices often fluctuate quite independently from the final product prices, it is natural for any phosphate fertilizer producer to try to avoid too heavy dependence on imported raw materials. In the opposite case, an increasing foreign currency expenditure might jeopardize the total economy of a phosphate fertilizer project.

2 BASIS OF PROCESS COMPARISON

The raw material cost structure varies widely between different products and processes. In this paper the primary raw material costs of the following products are broken down:

- TSP (triple superphosphate 0-46-0)
- DAP (diammonium phosphate 18-46-0)
- NPK (compound 15-15-15)

Moreover, regarding the manufacture of NPK fertilizers, the following three processes are compared:

- nitrophosphate (Odda) NPK process (plus CAN as by-product)
- urea-based NPK process
- phosphonitric (mixed acid) NPK process.

The following raw material prices are used in this paper:

		USD/t
-	Phosphate rock (33 % P_2O_5)	33
-	Sulphur	150
-	Ammonia NH_3	180
-	Urea	120
-	KCl	90
-	K_2SO_4	180

3 COST CALCULATIONS

The indicative raw material consumptions and costs are as follows:

		Raw material consumption t/t of product		Raw material unit price USD/t		Total raw material costs USD/t	%
TSP							
	P	1.48	x	33	=	48.84	51
	S	0.318	x	150	=	46.8	49
						95.64	100
DAP							
	P	1.49	x	33	=	49.17	31
	S	0.44	x	150	=	66	42
	NH_3	0.23	x	180	=	41.4	26
						156.57	99

NPK 15-15-15 KCl-based

		Raw material consumption t/t of NPK (plus CAN)		Raw material unit price USD/t		Total raw material costs USD/t	%
Odda + CAN							
	P	0.464	x	33	=	15.312	14
	NH_3	0.408	x	180	=	73.44	66
	K	0.205	x	90	=	22.5	20
						111.252	100
Urea-based							
	P	0.489	x	33	=	16.137	16
	S	0.145	x	150	=	21.75	22
N	NH_3	0.044	x	180	=	7.92	38
N	Urea	0.247	x	120	=	29.64	
	K	0.250	x	90	=	22.5	23
						97.947	99
Phosphonitric (Kemira)							
	P	0.470	x	33	=	15.51	18
	S	0.095	x	150	=	14.25	17
	NH_3	0.187	x	180	=	33.66	39
	K	0.250	x	90	=	22.5	26
						85.92	100

NPK 15-15-15 K_2SO_4-based

		Raw material consumption t/t of NPK (plus CAN)		Raw material unit price USD/t		Total raw material costs USD/t	%
Odda + CAN							
	P	0.464	x	33	=	15.213	11
	NH_3	0.408	x	180	=	73.44	51
	K	0.300	x	180	=	54	38
						142.752	100
Urea-based							
	P	0.489	x	33	=	16.137	12
	S	0.145	x	150	=	21.75	17
N	NH_3	0.044	x	180	=	7.92	29
N	Urea	0.247	x	120	=	29.64	
	K	0.300	x	180	=	54	42
						129.447	100
Phosphonitric (Kemira)							
	P	0.472	x	33	=	15.576	13
	S	0.106	x	150	=	15.9	13
	NH_3	0.188	x	180	=	33.84	28
	K	0.300	x	180	=	54	45
						119.316	99

In accordance with the above calculations, the shares of P, S, N and K raw material costs are graphically shown in Figure 1:

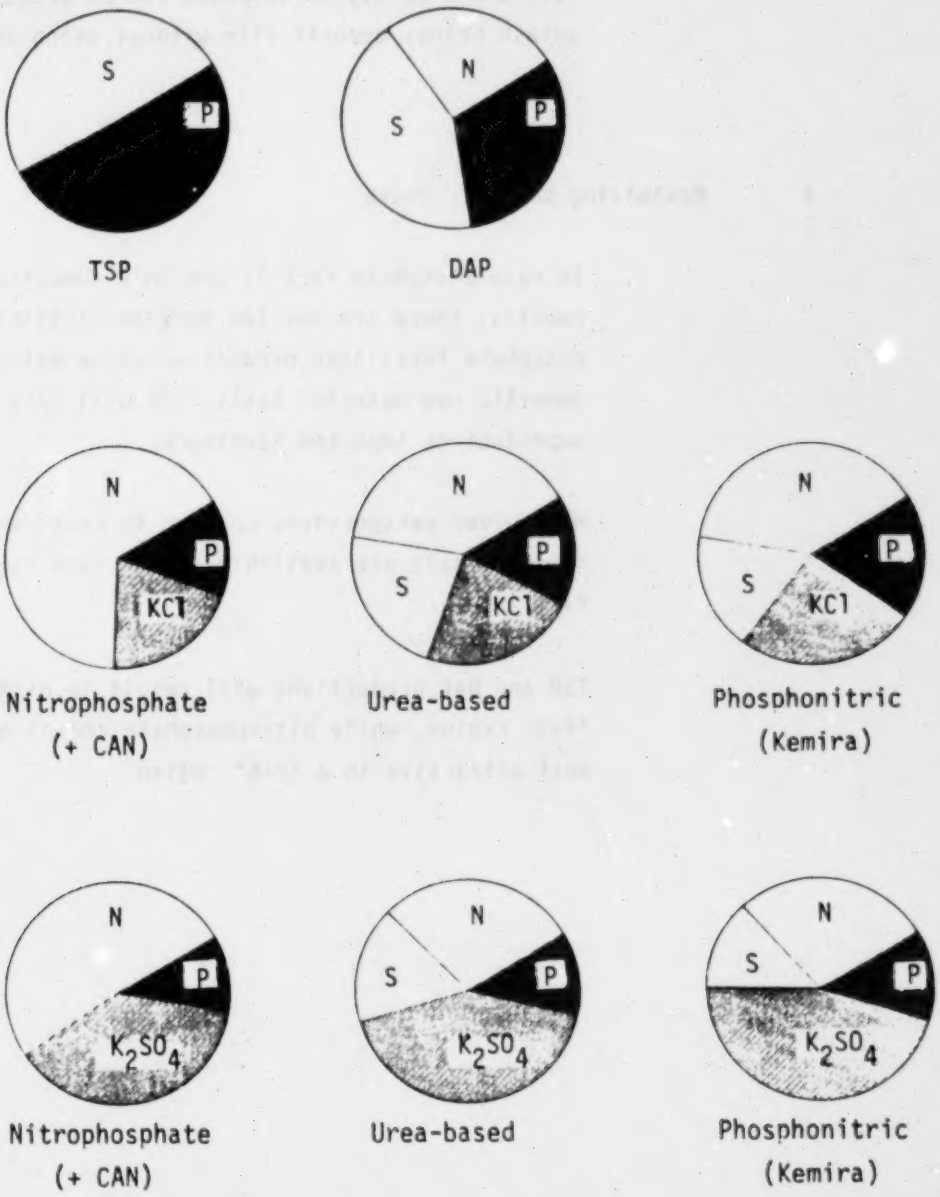

FIGURE 1 Shares of P, S, N and K raw material costs in various fertilizer processes

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It is to be noted that in this paper the potassium sulphate costs have not been broken down further into potassium chloride and sulphur costs. Thus the approach adopted here corresponds to a case where potassium sulphate can be produced directly at the potash brines deposit site without using sulphuric acid.

4 Maximizing Domestic Share

— In case phosphate rock is the only domestic raw material of a country, there are not too many possibilities to diversify phosphate fertilizer production while maintaining an essentially domestic raw material basis. TSP will here be the product least dependent on imported feedstocks.

— Much wider perspectives open up in cases where several domestic raw materials are available in the same region, e.g. P+S, P+N or P+K.

TSP and DAP productions will result in high domestic shares in a "P+S" region, while nitrophosphate (Odda) NPK production seems the most attractive in a "P+N" region.

5 Special Case:
Countries with Domestic Phosphate and Potash (P+K regions)

We shall now take a closer look at an example where a country possesses both phosphate rock and potash resources. The potash salt may be either potassium chloride or potassium sulphate (but produced without using sulphuric acid). In such conditions the share of domestic raw materials in the 15-15-15 grade NPK fertilizer production easily exceeds the corresponding share in DAP production, and might exceed even the figure attainable in TSP production if domestic potassium sulphate is available. The results of this approach are graphically shown in Figure 2.

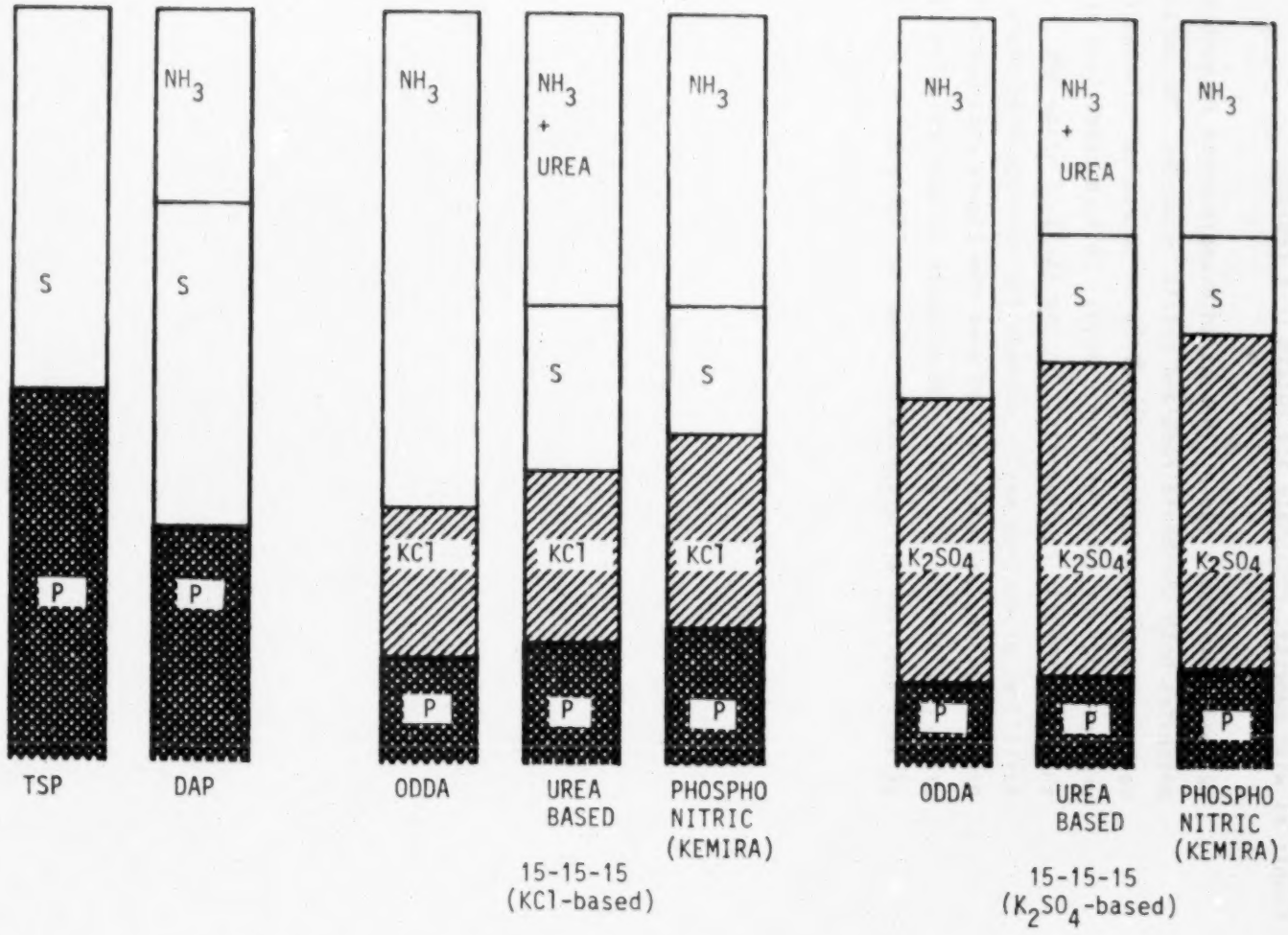

FIGURE 2. Domestic shares in "P+K" cases

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When comparing various NPK processes in a country with P+K resources, the target of maximizing the domestic share can also be formulated as follows:
"How to decrease the need of sulphur imporation?"

In this respect, the urea-based NPK process is the least attractive, because all phosphate rock must be converted into phosphoric acid by means of sulphuric acid.

On the contrary, the Odda NPK process avoids totally the importation of sulphur, but this advantage is more than offset by the fact that this process needs huge amounts of nitrogen raw material (ammonia) for the production of NPK's and by-product CAN. Moreover, as also CO_2 gas supply from ammonia plant is needed for CN conversion, the Odda process can hardly turn out feasible without an adjacent ammonia plant, and hence domestic nitrogen source.

Finally, the phosphonitric NPK process offers a fully realistic alternative of decreasing the importation of sulphur, although, unlike the Odda process, the need of sulphur is not totally eliminated, In this process a part of the phosphate rock is directly digested by nitric acid at the NPK plant, while another part of the phosphorus must still be introduced as phosphoric acid. In any case, for countries with phosphate rock and potash resources, the phosphonitric NPK process offers an attractive way of developing such downstream production which is still essentially based on domestic raw materials.

6 CONCLUSIONS

The raw materials of compound and phosphate fertilizer production are very seldom found all in one country. Careful planning is therefore needed to find out a production scheme which is best suited to the natural resources of each country. The variety of fertilizer processes available today enables the successful maximization of the share of domestic raw materials in each particular case.

Before the establishment of fertilizer industry, various processes and configurations shall always be compared in respect of several criteria, like:

- production costs
- investment costs
- product quality
- process flexibility
- environmental aspects
- etc.

Nevertheless, it is remarkable to see how often the simple maximization of the domestic share also leads to the optimal solution. In short, a predominantly domestic raw material basis gives a good guarantee for economical fertilizer production irrespective of international commodity price fluctuations.

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PRODUCTION COST COMPARISON BETWEEN NITROPHOSPHATE AND PHOSPHORIC ACID BASED FERTILIZERS*

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Summary

Stamicarbon has developed an improved variant of the nitrophosphate process with $Ca(NO_3)_2$ crystallization.
A production cost comparion between this nitrophosphate- and phosphosphoric acid-based 28:14:0 and 22.5:22.5:0 fertilizers, shows that the nitrophosphate based products have a cost advantage of about $ 100 per mton of P_2O_5 produced.

1. INTRODUCTION

1.1. STAMICARBON

Stamicarbon bv was established by DSM in 1947 for the purpose of commercializing proprietary processes developed by DSM, granting licences for these processes and providing services to customers.
The DSM process know-how is covered by some 7300 patents and patent applications and most of it is available for licencing. The know-how relates to single nutrient and compound fertilizers, urea, caprolactam, fenol and melamine, polymers and rubbers, mineral beneficiation, training and management consultancy and computer software.

The fertilizer know-how offered by Stamicarbon covers almost the full range of fertilizers. Most of the know-how is used in DSM's fertilizer division. DSM is one of the largest fertilizer producers in the world. Its eight production sites in Europe and the United States have a combined annual capacity of about 6.5 million mtons of fertilizer.
More than 300 urea, nitric acid, ammonium nitrate, superphosphate and compound fertilizer plants have been built all over the world on the basis of Stamicarbon know-how.

1.2. NITROPHOSPHATES

A nitrophosphate process may be defined as a process that calls for whole or partial treatment of phosphate rock with nitric acid. A principal advantage of nitrophosphate processes over sulphuric/phosphoric acid-based processes is that nitric acid is used for the dual purpose of (1) converting phosphate rock into soluble P_2O_5 and (2) furnishing nutrient nitrogen to the product.
Unlike phosphoric acid-based fertilizers, which require about 1 mton of sulphur per mton of P_2O_5, nitrophosphates do not require H_2SO_4 and are therefor independent of the sulphur market. In a period of soaring sulphur prices (which are expected to remain high for years to come (Figure 1)), various countries and companies are for both economical and political reasons increasingly anxious to become independent of sulphur prices and suppliers.
The development of the first nitrophosphate processes started in Europe (-1-) some 70 years ago.
Since then, a variety of processes have emerged (-2-). Most of them have in common that calcium has to be removed from the process, usually as $Ca(NO_3)_2$ or as $CaSO_4$.
Adapting to the changing requirements with respect to energy consumption, environmental protection, and quality of raw material (phosphate rock) supplies, Stamicarbon has developed an improved nitrophosphate process (-3,4-) based on the crystallization of calcium nitrate. This new process has been used for the cost comparisons described in the next chapters.

2. THE PRICE OF PHOSPHORIC ACID

As in all calculations, the results of variable cost calculations depend on the data-input used. In fertilizer cost evaluations the price of phosphoric acid often is the subject of discussion.

The variable cost of phosphoric acid is mainly determined by the costs of phosphate rock and sulphur. Sulphur prices (F.O.B.) have increased in the past decade (Figure 1) from US $ 75 to more than US $ 125 per ton.
Although in the long run phosphoric acid prices will surely follow the sulphur prices, as shown in Figure 2, a strange phenomenon can be observed. According to the cost calculations of the Stanford Research Institute (SRI Int. PEP Yearbook 1984), the production cost of phosphoric acid (at 100 % capacity realisation) and at $ 125 per ton sulphur, is about $ 390 per ton of P_2O_5.
Despite the increasing sulphur prices, the F.O.B. market prices of P_2O_5 have decreased to about $ 290 per ton.
It would seem that there is no short term relation between sulphur and phosphoric acid prices at all. The low P_2O_5 prices and costs can only be realized in large, depreciated phosphoric acid facilities, that are usually located at or near the phosphate rock mines and have long term, low price sulphur contracts.

This unnatural market situation cannot last very long and certainly should not be the basis for a long term strategy.
Newer facilities, especially if they have to import raw materials, can not afford to sell their acid for such low prices.
For this study a price of US $ 375 per ton of P_2O_5 has been used.

3. PRODUCTION COST COMPARISON

3.1. INTRODUCTION

Many papers have been published on this subject and have given rise to much debate and controversy. With respect to the production economics, almost all papers discuss only the NPK 1-1-1 grade produced from nitrophosphate with calcium nitrate crystallization, and compare this grade with those based on phosphoric acid. NPK grades with higher N/P_2O_5 ratios are usually ignored, although a ratio of 2 would reflect the actual overall nitrogen and phosphate demands in many countries more accurately.
The present evaluation covers the production economics of the products with grade $N:P_2O_5:K_2O$ 28:14:0 and 22.5:22.5:0, produced by the new Stamicarbon nitrophosphate process (Figure 3) in comparison with the phosphoric acid based route.

3.2. ASSUMPTIONS

With the production of 28:14:0, all off the NH_4NO_3 produced in the $Ca(NO_3)_2$ conversion plant is recycled to the nitrophosphate plant, and no additional (Calcium-) Ammonium Nitrate is produced.
The phosphoric acid based products need a filler to produce the required grade. As usually a higher grade will be produced, the cost of filler is not included in the comparison.
During the production of 22.5:22.5:0, a proportion of the NH_4NO_3 solution (80 % concentration) produced is recycled to the NP plant the remainder is concentrated to 99 % and prilled.
The value of the NH_4NO_3 produced is credited (at $ 119/mt NH_4NO_3) to the nitrophosphate process.
The production capacity used in this evaluation is 70,000 mt of P_2O_5/year, or 500,000 mt of 28:14:0 and 311,000 mt of 22.5:22.5:0 per year.

The investment estimates used are:

Production based on:	28:14:0	22.5:22.5:0
Phos. Acid	$ 22 x 10^6	$ 16 x 10^6
Nitrophosphate	$ 37 x 10^6	$ 32.3 x 10^6
NH_4NO_3, from 80 % solution	-	$ 6 x 10^6

The variable cost of NH_4NO_3 production is estimated at $ 8/mton. Phosphate rock contains 32 % P_2O_5 and 50 % CaO.

The total annual fixed costs are assumed to be 34 % of investment.

The production of sulphuric and phosphoric acid is not included in this comparison. Phosphoric acid is purchased outside, and CO_2 is available at no cost as a byproduct from ammonia production.

3.3. RESULTS

A summary of the production cost calculations is presented in the Tables 1 and 2.
At the conditions choosen, 2.7 ton of NH_4NO_3 is produced in conjunction with each ton of P_2O_5 as 22.5:22.5:0.
The total production cost of the nitrophosphate-based 28:14:0 product is found to be about $ 110 less than that of the phosphoric acid-based product.
For the 22.5:22.5:0 fertilizers, after crediting for the NH_4NO_3 produced, this difference is about $ 80. In both cases the difference is the balance of the higher fixed and lower variable costs of the nitrophosphate-based production route.
The variable costs of P_2O_5 for the nitrophosphate process are about $ 250 lower than for the phosphoric acid based route.

4. CONCLUSIONS

* The economics of the nitrophosphate process are independent of the sulphur and phosphoric acid prices.

* Nitrophosphate fertilizers are cheaper to produce than phosphoric acid based products.

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3. M.H.G. Jennekens and G.H.M. Calis 'Significant Energy Savings In The ODDA Process', IFA Techn. Conf., Paris France, Nov. 1984.

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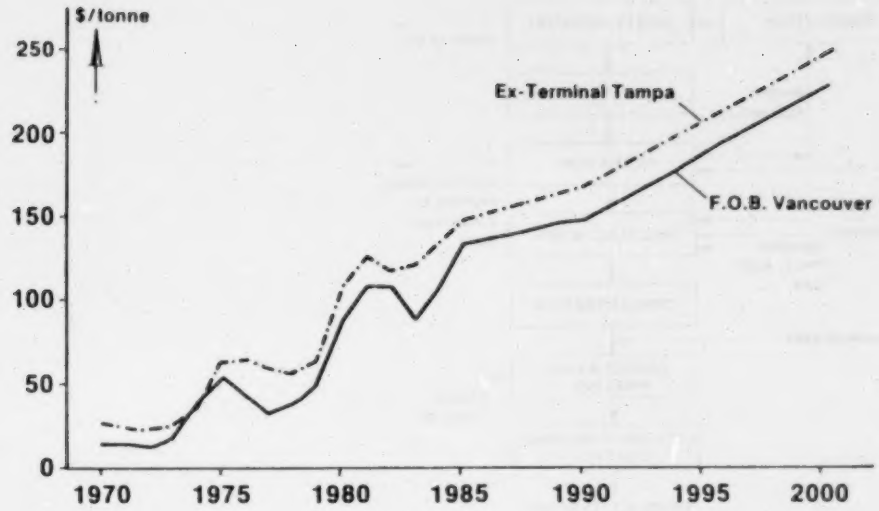
Table 1: Production costs of 28:14:0.

Variable costs/mton of P_2O_5:	Unit price	Nitrophosphate Quantity	Nitrophosphate Cost	Phos. Acid-based Quantity	Phos. Acid-based Cost
Phosphoric acid, mton P_2O_5	375	0	0	1.02	382.5
Phosphate rock, mton	40	3.21	128.4	0	0
Nitric acid, mton	75	4.16	312	4.11	308.3
Ammonia, mton	220	1.35	297	1.36	299.2
Steam, mton	12	4.5	54	0.73	8.8
Water, m^3	.04	220	8.8	0	0
Electricity, kWh	.051	385	19.6	220	11.2
Fuel, Gcal	14.7	.9	13.2	.44	6.5
Total variable costs:		US $	833	US $	1016.5
Total fixed costs, 34 % of investment:			179.7 +		106.9 +
Total production costs/mton of P_2O_5:		US $	1012.7	US $	1123.4

Table 2: Production costs of 22.5:22.5:0

Variable costs/mton of P_2O_5:	Unit price	Nitrophosphate Quantity	Nitrophosphate Cost	Phos. Acid-based Quantity	Phos. Acid-based Cost
Phosphoric Acid, mton P_2O_5	375	0	0	1.02	382.5
Phosphate rock, mton	40	3.21	128.4	0	0
Nitric acid, mton	75	3.98	298.5	1.81	135.8
Ammonia, mton	220	1.3	286	0.75	165
Steam, mton	12	4.6	55.2	0.63	7.6
Water, m^3	.04	220	8.8	0	0
Electricity, kWh	.051	400	20.4	200	10.2
Fuel, Gcal	14.7	0.7	10.3	0.34	5
NP Plant: Variable costs		US $	807.6	US $	706.1
Fixed costs (34 % of investment)			156.9		77.7
NH_4NO_3 plant: Variable costs			21.4		0
Fixed costs (34 % of investm.)			29.1 +		0 +
Subtotal, prod. costs/mton P_2O_5			1015		783.8
Credit for NH_4NO_3 produced			317.7 -		0 -
Total production costs/mton of P_2O_5:		US $	697.3	US $	783.8

Sulphur price



Source: Proceedings No. 234 of the Fertiliser Society London

Figure 1

Sulphur and Phosporic Acid Prices; 1970-1982

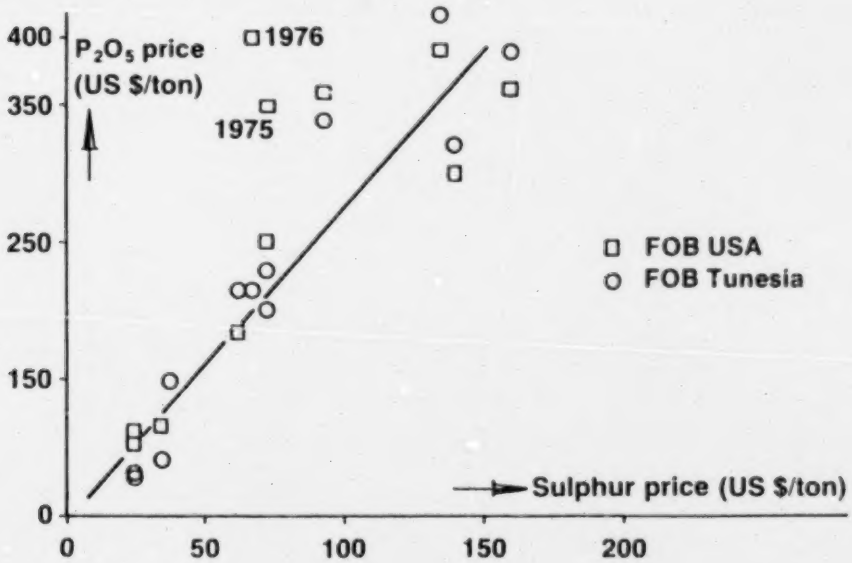


Figure 2

Block diagram of Stamicarbons Nitrophosphate Crystallization Process

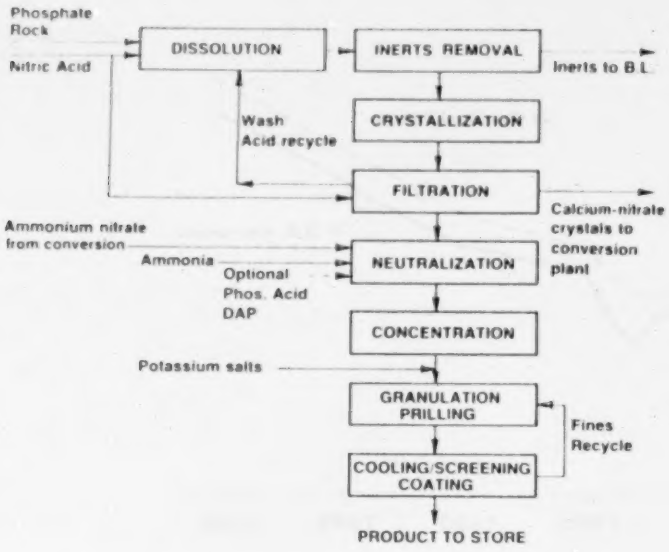


Figure 3

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Round-Table Discussions on the Development of Phosphates and Phosphate Fertilizer Industry in Developing Countries

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WORLD PHOSPHATE FERTILIZER SUPPLY/DEMAND TRENDS*

Prepared by

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SUMMARY

The paper presents a review of statistical data on the production; supply potential; consumption respective demand; use (consumption per ha); and prices of phosphates, compiled from various sources of world-wide recognition.

The tables comprise averaged regional figures and data on relevant producer/consumer and exporting/importing countries, with an indication of their ranking which changed significantly over the past decade.

Conclusions are drawn on the basis of past trends and projections, taking into account the planned growth of phosphoric acid production capacities. The attention is focussed on the changing pattern of the global supply/demand situation influenced by decreasing consumption growth rates. The increasing share of the developing countries' production and consumption within the respective world totals are highlighted.

Macro-economic problems which have induced a world-wide decline of consumption over the past three years are shown as an important factor of the present trend. The supply/demand outlook presented in the paper reveals a relatively large surplus of phosphate fertilizer availability throughout the next five years, and suggests that this factor is indicative of the development trend of the phosphate fertilizer industry for the nearest future.

WORLD PHOSPHATE FERTILIZER SUPPLY/DEMAND TRENDS[1]

Production

It has not been a good year for most phosphate producers. Prices of most phosphate products have declined while the production costs of inputs such as sulfur have increased substantially. A record 34 million mt of phosphate fertilizers, excluding phosphate rock, was produced in 1983/84[1] (Table 1). Ten years earlier (1973/74) only 25 million mt of phosphate fertilizers was produced. North America was the biggest producing region in both years, producing about 27% of the world's total in 1983/84. Production in Western Europe declined significantly during this period, whereas production in Asia and the U.S.S.R. increased significantly, going from 12% each in 1973/74 to 19% and 18%, respectively, of the world's total in 1983/84. Asia was the region that had the fastest growth in production, increasing at a rate of 8.4% annually. Africa increased at about 5.8% annually. Developed countries as a whole increased production at the annual rate of 1.8% during the past decade while developing countries increased production of phosphates at an annual rate of 9.0%.

Table 1. World: Fertilizer Production by Region, 1973/74 and 1983/84[a]

Area	P_2O_5 (million mt)	% World 1973/74	P_2O_5 (million mt)	% World 1383/84	Annual Compound Growth Rate (%)
North America	6.9	28	9.2	27	2.9
Latin America	0.7	3	1.3	4	5.9
Western Europe	6.4	26	5.1	15	-2.3
Eastern Europe	2.5	10	3.1	9	2.2
U.S.S.R.	3.0	12	6.1	18	7.4
Asia	3.0	12	6.6	19	8.4
Africa	0.9	4	1.7	5	5.8
Oceania	1.6	6	1.0	3	-5.0
TOTAL WORLD	25.0	100	34.0	100	3.1
Developed Countries	21.5	86	25.6	75	1.8
Developing Countries	3.5	14	8.4	25	9.0
TOTAL WORLD	25.0	100	34.0	100	3.1

a. Does not include ground phosphate rock. Calendar year data for 1983 would be included with 1983/84. Totals may not add due to rounding.

Source: FAO.

The United States, U.S.S.R., China, France, and India rank as the top five producers and consumers of phosphate fertilizer. India has replaced Brazil in the top five in both categories during the latest year. The top five countries

1. The primary data source used in this paper is the Food and Agriculture Organization of the United Nations (FAO). The latest year for FAO's published fertilizer statistics is 1983/84.

produced 58% of the 34 million mt of finished phosphate fertilizers (excluding ground phosphate rock used for direct application).

Dwindling worldwide sulfur supplies coupled with increasing demand since 1984 sharply increased sulfur prices, which reached record levels during July 1985 but have declined since then. High sulfur prices have sharply increased the production cost of most phosphate fertilizers. The U.S. Bureau of Mines data indicate that world sulfur consumption exceeded world production by about 3 million mt in 1984. Other analysts indicate that the shortfall may have been even higher. The deficit was met by reducing inventories in Canada. These inventories in 1978 totaled 21 million mt but were reduced 3 million mt last year and now total 12 million mt, some of which may not be available. Sulfur supplies are expected to be tight throughout the 1980s.

Consumption

The political and economic events of the past decade have had a major impact on phosphate consumption. In the 1970s many developed countries designed policies to increase food production, particularly for export. Developing countries reacted to the 1974 food and fertilizer crisis by launching programs to become more self-sufficient in food production. These policies stimulated fertilizer consumption particularly in the late 1970s.

In the 1980s farmers in developed countries achieved record levels of agricultural production, which resulted in low prices at a time when their production costs continued to increase. In order to reduce production costs farmers have maintained past levels of phosphate use or have cut back on use. In developing countries shortages of foreign exchange, high inflation, high interest rates, high military expenditures, low demand for exports from developing countries, balance of payment constraints, high subsidy costs, and growing debt service payments have also made it difficult for the fertilizer sector to develop. These factors have resulted in world phosphate consumption declining in 2 of the past 3 years (1981/82 and 1982/83).

Phosphate fertilizer consumption during the past decade has increased from 24.2 million mt in 1973/74 to 31.8 million mt in 1983/84 for an annual growth rate of only 2.8% (Table 2). The major growth market has been Asia which consumed 16% of the world's total in 1973/74 but now consumes 27%. The U.S.S.R.'s share of consumption has increased from 11% in 1973/74 to 18% in 1983/84. In 1973/74 North America and Western Europe consumed almost one-half of the world's total but now consume less than one-third of the world's total; each region's share of the world's total has declined significantly.

Table 2. Phosphate Fertilizer Consumption by Region, 1973/74 and 1983/84[a]

Area	P_2O_5 (million mt)	% World 1973/74	P_2O_5 (million mt)	% World 1983/84	Annual Compound Growth Rate (%)
North America	5.1	21	5.2	16	0.1
Latin America	1.3	5	1.7	5	2.5
Western Europe	6.0	25	5.1	16	-1.6
Eastern Europe	2.8	12	3.3	10	1.8
U.S.S.R.	2.7	11	5.7	18	7.6
Asia	3.9	16	8.5	27	8.0
Africa	0.7	3	1.1	3	5.1
Oceania	1.6	7	1.1	3	-3.7
TOTAL WORLD	24.2	100	31.8	100	2.8
Developed Countries	19.4	80	21.5	68	1.1
Developing Countries	4.8	20	10.2	32	7.8
TOTAL WORLD	24.2	100	31.8	100	2.8

a. Does not include ground phosphate rock for direct application. Calendar year data for 1983 is included with 1983/84. Totals may not add due to rounding.

Source: FAO.

Ten years ago the developing countries consumed one-fifth of the world's phosphate fertilizers. This share has increased to one-third of the world's total during the 10-year period. Growth rates in the developing countries have been 7.8% annually during the past decade, whereas the growth in developed countries has been only 1.1%. The top five consumer countries were also the top five producers (Table 3). These five countries consume about 53% of the world's phosphate. The U.S.S.R. ranks first in consumption and the United States second in consumption, whereas this order is reversed in the production rankings.

During the past 10 years phosphate use has increased at a slower rate than nitrogen use in both developed and developing countries. In developed countries phosphate use has also increased slower than potash use, but in developing countries phosphate use has increased faster than that of potash.

Use Per Hectare

In phosphate consumption per hectare, seven of the ten highest countries are in Western Europe (Table 4), where consumption averaged 56 kg/ha in 1982 (latest data available). The developed countries as a group consumed about 31 kg/ha of P_2O_5. The average for the world was 21 kg/ha, for Asia 17 kg/ha, and for developing countries 12 kg/ha. Consumption in Africa averaged only 6 kg/ha, considerably below the average for other developing regions.

Trade

The United States is the world's leading exporter of finished phosphate fertilizers followed by Tunisia, Belgium-Luxembourg, Morocco, and the Netherlands

Table 3. World's Top Ten Phosphate Fertilizer Producers, Consumers, and Traders (1983/84)

Country	Production			Consumption			Imports			Exports		
		World Rank			World Rank			World Rank			World Rank	
	1983/84 ('000 mt)	1973/74	1983/84	1983/84 ('000 mt)	1973/74	1983/84	1983/84 ('000 mt)	1973/74	1983/84	1983/84 ('000 mt)	1973/74	1983/84
United States	8,597	1	1	4,472	1	2	109	3	19	3,948	1	1
U.S.S.R.	6,108	2	2	5,683	2	1	121	36	18	312	9	6
China	2,666	4	3	3,671	3	3	1,005	9	1	0	NA	NA
France	1,230	3	4	1,614	4	4	560	1	2	110	7	12
India	1,059	20	5	1,344	10	5	143	5	13	0	NA	NA
Brazil	922	21	6	866	9	7	0	2	NA	56	32	23
Poland	872	NA	7	900	7	6	37	112	39	3	21	41
Romania	733	16	8	537	18	14	0	NA	NA	196	17	8
Canada	655	10	9	713	12	11	151	31	11	94	4	14
Japan	647	9	10	766	8	8	158	19	10	31	22	27
West Germany	552	6	14	745	6	9	355	7	4	149	6	10
Australia	597	5	13	728	5	10	174	85	9	0.3	NA	46
Tunisia	514	26	16	38	61	61	0	NA	NA	485	5	2
Belgium-Lux	515	8	15	97	27	38	62	17	29	480	2	3
Morocco	493	28	17	96	50	39	0.4	NA	119	387	8	4
Netherlands	403	17	21	86	35	43	50	13	34	348	3	5
Korea Rep.	458	30	18	171	24	29	0	16	NA	266	NA	7
Jordan	144	NA	35	7	108	86	5	93	73	170	NA	9
Iran	4	38	63	427	32	17	423	27	3	0	NA	NA
Italy	616	12	12	682	14	12	313	12	5	79	19	19
Hungary	233	25	29	410	20	18	241	6	6	33	NA	26
United Kingdom	317	14	26	462	13	16	191	18	7	49	12	25
Pakistan	92	61	41	258	43	26	180	10	9	0	NA	NA
TOTAL	28,427			21,469			4,278			7,196		
Other countries	5,607			10,286			2,429			988		
World Total	34,034			31,755			6,707			8,184		

Notes: Countries listed are those that were ranked in the top ten in either production, consumption, imports, or exports in 1983/84. Information does not include ground phosphate rock for direct application.

Source: Derived from FAO data.

Table 4. Use of Phosphate[a] Per Hectare, 1982[b]

Africa			Asia			Latin America			Developed Countries		
Rank	Country	kg/ha	Rank	Country	kg/ha	Rank	Country	kg/ha	Rank	Country	kg/ha
1	Egypt	60.6	1	Japan	149.3	1	Cuba	25.4	1	New Zealand	702.1
2	South Africa	37.0	2	Korea Rep.	68.3	2	Uruguay	24.8	2	Iceland	112.5
3	Mauritius	28.8	3	Korea, DPR	57.3	3	Mexico	20.8	3	Ireland	149.4
4	Libya	20.5	4	Lebanon	45.0	4	Costa Rica	20.2	4	Belgium-Lux	113.1
5	Zimbabwe	16.2	5	Israel	37.6	5	El Salvador	17.3	5	Switzerland	106.3
6	Kenya	12.9	6	China	31.6	6	Brazil	16.2	6	Germany FR	99.1
7	Algeria	9.8	7	Iran	29.2	7	Colombia	14.8	7	Czechoslovakia	92.6
8	Morocco	9.6	8	Saudi Arabia	29.2	8	Venezuela	12.6	8	Netherlands	89.9
9	Tunisia	8.0	9	Malaysia	25.6	9	Panama	11.0	9	France	87.6
10	Mozambique	4.2	10	Turkey	20.7	10	Guatemala	10.1	10	Bulgaria	87.0
11	Zambia	3.6	11	Indonesia	18.2	11	Chile	8.1	11	Norway	77.9
12	Malawi	2.2	12	Cyprus	15.1	12	Ecuador	7.0	12	Hungary	73.9
13	Ghana	2.0	13	Bangladesh	14.3	13	Nicaragua	5.1	13	Finland	67.8
14	Nigeria	1.9	14	Sri Lanka	14.1	14	Dominican Republic	4.6	14	United Kingdom	66.5
15	Senegal	1.8	15	Pakistan	13.1	15	Peru	3.6	15	Germany DR	60.8
16	Ivory Coast	1.8	16	Syria	9.5	16	Honduras	1.5	16	Poland	55.6
17	Ethiopia	1.5	17	India	7.1	17	Argentina	1.4	17	Italy	52.9
18	Cameroon	.7	18	Thailand	6.9				18	Romania	51.8
19	Tanzania	.5	19	Vietnam	6.3				19	Austria	51.0
20	Sudan	0.0	20	Philippines	4.3				20	Greece	44.9
			21	Burma	4.3				21	Denmark	42.8
			22	Nepal	3.5				22	Albania	40.9
			23	Iraq	2.2				23	Sweden	38.6
			24	Afghanistan	1.8				24	Yugoslavia	30.0
									25	U.S.S.R.	26.3
									26	Portugal	22.2
									27	Spain	20.6
									28	United States	19.8
									29	Australia	15.5
									30	Canada	14.1

a. Includes countries using 20,000 nutrient tons or more.
b. Per hectare of arable land and land in permanent crops.

Source: 1983 FAO Fertilizer Yearbook (latest available).

(Table 3). During the past 10 years Morocco has replaced Canada in this elite group; the other four countries were among the top five exporters in 1973/74. The United States exports almost one-half of the world's phosphate fertilizers. The top five countries export 69% of the world's total. About 8 million mt of phosphate was exported in 1983/84 by all countries. China was the largest importer of phosphate fertilizers followed by France, Iran, West Germany, and Italy. These five countries account for about 40% of the world's phosphate imports. France is the only one of these countries that ranked in the top five in 1973/74; the other four were Brazil, United States, Turkey, and India.

Prices

Figure 1 shows weekly international prices of TSP, f.o.b., U.S. Gulf. Triple superphosphate prices increased from 1978 through early 1981 and reached a high of $196/mt in March 1980; they then retreated and again advanced in early 1981, reaching a new high of $206/mt in February 1981. In July 1985, they declined to $110/mt. As TSP prices were declining prior to July, sulfur prices were increasing, reaching a high of $152/mt f.o.b. Vancouver in July. This has caused a number of phosphate producers in the United States to temporarily cut back their operations. Diammonium phosphate prices (DAP) have fluctuated somewhat similarly to those of TSP, reaching a high of $260/mt in January 1980 and then declining and reaching a 5-year low of $158/mt in July 1985. Prices have increased since then.

Supply/Demand Outlook

In trying to forecast the phosphate fertilizer situation, let us look at the future supply first. North America has, by far, the largest amount of phosphoric acid capacity with about 11.7 million mt of the world's total of 33.5 million mt in 1985 (Table 5). Africa is expected to increase its capacity from 4.1 million mt in 1985 to about 6.2 million mt in 1990 which will exceed considerably the increases expected in other regions. Countries projected to make the largest increases in phosphoric acid capacity during the next 5 years include Morocco, U.S.S.R., Tunisia, Mexico, and Brazil (Table 6). A 10% increase in phosphoric acid capacity worldwide is expected between 1985 and 1990, slightly lower than the projected growth in ammonia capacity. On the basis of preliminary supply/demand projections prepared by the FAO/UNIDO/World Bank Working Group on fertilizers in June 1985, wor fertilizer consumption is expected to reach 152.9 million mt of plant nutrients in 1989/9 compared with 129.3 million mt estimated for 1984/85.

Table 5. World Phosphoric Acid Capacity by Region, 1970-90 Projected

	1970	1976	1980	1985	1990	Change 1985-90
	(million mt P_2O_5)					
North America	6.4	9.2	10.4	11.7	10.8	-.9
Latin America	0.6	0.7	0.8	1.2	1.9	0.7
Western Europe	3.5	4.7	4.6	4.3	4.4	0.1
Eastern Europe	0.5	1.4	1.9	2.1	2.3	0.2
U.S.S.R.	0.9	2.4	3.2	5.4	6.2	0.8
Africa	0.7	1.6	2.7	4.1	6.2	2.1
Asia	1.3	2.2	2.9	4.4	4.7	0.3
Oceania	0.2	0.2	0.2	0.3	0.3	0.0
WORLD TOTAL	14.1	22.4	26.7	33.5	36.8	3.3

Source: TVA, September 6, 1985.

The Working Group's projections indicate that phosphate consumption will increase from 34.0 million mt of P_2O_5 in 1984/85 to 40.2 million mt of P_2O_5 by 1989/90[2] (Figure 2). This would be a growth of about 3.5% annually. About 55% of the projected growth is expected to occur in developing countries. The available phosphate supply is projected to increase from 37.4 million mt of P_2O_5 in 1984/85 and reach 42.6 million mt of P_2O_5 in 1989/90. Over two-thirds of this growth will be in North Africa and other developing countries. These projections indicate a large surplus of phosphate fertilizers throughout the next 5 years.

Summary

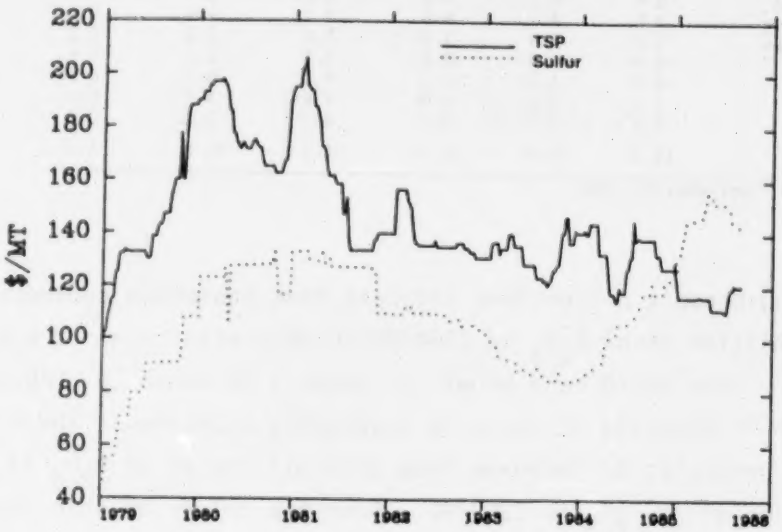
Phosphate production during the past 10 years has increased at a rate of 3.1% annually. Increases in sulfur prices and declines in prices of phosphate products have made 1985 a bad year for most producers. Five countries produce 58% of the phosphates, and five countries account for 69% of the world's exports. Asia and the U.S.S.R. have increased in importance as producing and consuming regions during the past decade while Western Europe's importance has declined.

A worldwide recession and low farm commodity prices, high interest rates, and foreign exchange problems have reduced the demand for phosphate fertilizers. As a result, phosphate consumption worldwide has declined during 2 of the past 3 years. During the past 10 years, growth in consumption has averaged only 2.8% annually.

A surplus of phosphates is projected for the next 5 years. The biggest increases in phosphoric acid capacity are projected for Morocco, U.S.S.R., and Tunisia.

2. Projections include phosphate rock used for direct application.

Figure 1. Sulfur and TSP Prices.



Source: Green Markets

Sulfur f.o.b. Vancover
TSP f.o.b. U.S. Gulf

Figure 2. World Total P_2O_5 Fertilizer Supply and Demand (Includes Ground Phosphate Rock).

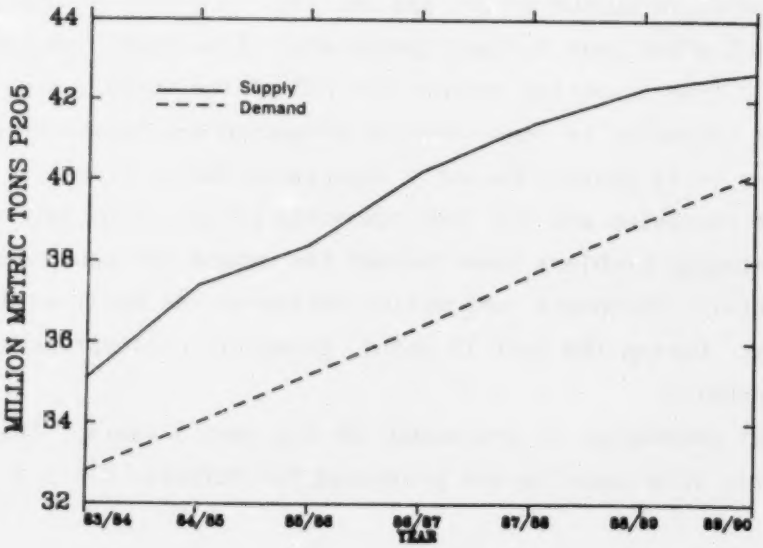


Table 6. Ten Countries With Largest Announced Increases in Phosphoric Acid Capacity, 1985-90 Projected

Rank	Country	1985	1990	Increase	% Increase
		('000 mt P_2O_5)			
1	Morocco	1,485	2,805	1,320	89
2	U.S.S.R.	5,379	6,194	815	15
3	Tunisia	1,125	1,690	565	50
4	Mexico	546	942	396	73
5	Brazil	667	982	315	47
6	Indonesia	180	360	180	100
7	Algeria	165	330	165	100
8	Poland	496	639	143	29
9	Yugoslavia	740	835	95	13
10	Sweden	170	220	50	29
TOTAL OTHER		22,594	21,954	-640	-3
TOTAL WORLD		33,544	36,951	3,407	10

Source: TVA, September 6, 1985.

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RESEARCH AND DEVELOPMENT FOR PHOSPHATE RECOVERY AND PHOSPHATE FERTILIZER PRODUCTION FROM IRON ORE CONCENTRATION TAILS AT SIERRA GRANDE, ARGENTINA*

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Summary

The tails of the iron ore concentration plant at Sierra Grande are the only known commercially available phosphate resources in Argentina (Annually 65,000 tons of P_2O_5 at rated capacity), where the increase in the use of fertilizers is being promoted. Under a bilateral technical cooperation scheme between the Government of Japan and Argentina, a feasibility study has been undertaken covering the concentration of apatite from the tails and the production of seven type of phosphate fertilizers using the high-Fe phosphate concentrate thus obtained. Two technically viable options (MAP/DAP and NP) were selected for financial and economic analysis, which showed marginal feasibility under the present depressed international phosphate fertilizer market. Efforts are being continued to seek economic recovery of the P_2O_5 values as well as the production of phosphate fertilizer in Argentina.

1. General Features of Agriculture and Fertilizer in Argentina

Grain production and cattle raising have traditionally been relevant to Argentina's economy. The present outputs of the agricultural sector contributed 13% of the gross domestic production, while the share of agricultural products and primary commodities in the total exports was 75%. Agriculture is the key industry of the country. The area in million hectares devoted to the arable and permanent crops is 35.8 and to the pernament pasture is 143.0, respectively.

It is characteristic of the country's agriculture the coexistence of extensive and intensive farmings. The former is typified by grain production and pastures, mainly located in the Pampeana region. Intensive farming produces vegetables, fruits, tobacco, sugar cane and others in areas such as the Provinces of Mendoza, San Juan, Salta, Corrientes and Rio Negro.

The use of fertilizers was first introduced for intensive farming, where its use has reached at present a relatively high level. On the other hand, fertilization for extensive agriculture has been traditionally low, to the extent that the overall consumption of fertilizers in Argentina in terms of kilograms of the three nutrients per hectare is among the lowest in the world: 0.6 kg/agriculture area, 3.1 kg/arable and permanent crops, and 14.5 kg/capita.

Consumption of phosphate fertilizer amounted in 1984 to some 47,000 tons of P_2O_5, 30,000 of which correspond to extensive farming and the rest to intensive agriculture. The INTA (Instituto Nacional de Tecnologia Agropecuaria) has demonstrated the need of a substantial increase in the use of phosphate fertilizers, both to raise productivity and to reverse the diminishing availability of natural phosphates in the soil of agricultural lands. Consumption of nitrogen and potash nutrients in 1984 were 98,000 and 11,400 tons, respectively.

Starting in 1984 the use of fertilizers is being stimulated by the authorities, mainly in connection with extensive farming, aiming at the increase of grain production for the export market. This policy has resulted in a marked increase in fertilized areas and yields. Projection of the estimates to 1990/95 indicates that, under favourable conditions, phosphate fertilizer consumption can reach a level of 100,000/150,000 tons of P_2O_5.

Regarding the relative evaluation among potential phosphate fertilizers in connection with the soil and agricultural conditions in Argentina:

a) In general, phosphate fertilizers with high water solubility, such as in SSP, TSP and MAP/DAP, are more suitable. Marketability of acid soluble phosphates (such as ground phosphate rock or fused magnesium

phosphate) is limited to the Mesopotamic area in the Northeast, and to pastures.

b) Compound fertilizers are used in intensive farming, while extensive farming applies mainly nitrogen or phosphate fertilizers separately, as straight fertilizers.

c) Although nitrophosphate has not been widely accepted in Argentina so far, it is judged possible that a market for this product can be developed, especially in the intensive farming sectors. Of course, a proper preparation procedure would be required for a rapid switch from the traditionally used phosphate fertilizers to nitrophosphate fertilizer.

d) Regarding the coproduct of nitrophosphate such as CAN or AN, if the use of nitrogen fertilizer is increased among the wheat growers in the Southern Pampeana region, it is possible that a market for these products can be developed.

2. Fertilizer Production

Argentina has adequate natural gas reserves, but only one medium scale nitrogen fertilizer plant with daily ammonia production capacity of 190 tons is producing urea and ammonium sulfate, and is still depending on nitrogen fertilizer imports. Recently discovered potash reserves in Malargue, Mendoza, are under study for development, while the iron ore concentration tails in Sierra Grande, Rio Negro represent the only known source of domestic phosphates. Fertilizer production based on these natural resources could significantly contribute to the economic recovery and development of the country.

The Sierra Grande tails are presently a waste product from the iron ore concentration plant located at Sierra Grande, Rio Negro, and operated by Hierro Patagonico de Sierra Grande S.A.M. (HIPASAM). The company, owned by the Argentine government, started commercial production of iron ore pellets in 1979, the product being shipped to supply the blast furnaces of SOMISA, San Nicolas, North of Buenos Aires. The production of direct reduction quality iron ore pellets is also being considered.

The Sierra Grande ore is a sedimentary magnetite containing 54.8% Fe and 3.2% P_2O_5, mainly as hydroxyapatite, fluorapatite and other complex minerals. The beneficiation process includes crushing, dry magnetic separation, wet grinding and magnetic separation for reducing P_2O_5 to approximately 0.69%, followed by reverse flotation lowering P_2O_5 content to around 0.27%. As a result, a concentrate containing 68% Fe is obtained, which is later pelletized. The processing of ore to produce at the rated annual capacity of 2.0 million tons of pellets would generate 920,000 tons of magnetic separation tails with 27.5% Fe and 7.1% P_2O_5, equivalent to 65,000 tons of P_2O_5. These tails are finely ground (85% under 400 mesh) and, as mentioned before, are the only available phosphate source identified to date in Argentina.

3. Feasibility Study on Phosphate Fertilizer Production

In December 1982, HIPASAM, the Direccion General de Fabricaciones Militares (DGFM) and the Japan International Cooperation Agency (JICA) started a feasibility study under bilateral technical cooperation scheme for the establishment of a phosphate fertilizer plant using the Sierra Grande tails as raw material. The JICA appointed UNICO, Japan, to perform the study, which was completed in August of 1984.

4. Phosphate Recovery

A representative sample of 700 kg of tails was obtained at Sierra Grande in 1983 and used in laboratory and pilot plant scale tests on phosphate concentration and also to conduct mineralogical studies; 15 kg of apatite concentrate were produced and used for evaluation tests for the conceptual design of seven alternative scheme for the production of phosphate fertilizers. The results of the concentration tests were the following:

a) Phosphate minerals in the tails are mainly fluorapatite and hydroxyapatite; apatite crystals are locked with iron minerals and chlorite.

b) Minor phosphate minerals other than apatites have been detected; these are blue and brown colored and include iron as a constituent.

c) There are inclusions of iron minerals in apatite crystals and the iron minerals seem partly diffused in the apatite crystals.

d) A small amount of iron is homogeneously dispersed over the entire surface of the apatite crystals, as detected by X-Ray observation.

e) Even if the tails are ground to diameter of 0.01 mm, it is impossible to achieve crystal grain isolation or liberation of iron minerals, chlorite and apatites.

f) Chlorite, which contains iron, has a Zeta potential similar to that of apatites; consequently, the concentration of phosphate rock from chlorite by flotation and magnetic separation would be difficult.

g) With the purpose of determining the lower limit attainable for residual iron in the phosphate rock, HGMS (high gradient magnetic separation) was also applied; a highly purified phosphate rock of 39.55% P_2O_5 and 1.84% Fe was obtained. However, even when the product grade was improved, the P_2O_5 recovery was 22.1% and was judged to be not suitable for industrial application at the present state of the art.

h) The concentration of phosphate rock by flotation, due to the specific characteristics of the Sierra Grande ore, requires a higher than normal consumption of electric energy for intensive grinding, as well as of flotation collector; the P_2O_5 recovery is also relatively low. The situation in Sierra Grande is differ from that of Svenskt Stål, Grängesberg, Sweden or Luossavaara Kürunavaara AB, Kiruna, Sweden where purified phosphate rock is commercially produced at higher P_2O_5 recovery rate from magnetite ore concentration tails.

On the basis of the concentration tests results, it was confirmed that the following conceptual design for the phosphate rock concentration plant would be rational:

- Phosphate rock quality:	P_2O_5	36.0%
	Fe	6.0%
	CaO	44.3%
	F	1.5%
- Recovery of P_2O_5:		56.0%
- Concentration process:	Grinding, rougher flotation, cleaner flotation (5 stages), sedimentation, filtration and drying.	
- Annual production capacity:	Phosphate rock;	100,000 tons
	P_2O_5 ;	36,000 tons
- Plant location:	Sierra Grande, Rio Negro, Argentina	

5. Phosphate Fertilizer Production

No precedent exists in the world for the production phosphate fertilizer from a phosphate rock of this quality, especially regarding its Fe content, making it necessary to undertake evaluation and trial tests for the seven phosphate fertilizer alternatives. Conceptual design of such plants were prepared.

During the tests, the following specific characteristics of the phosphate rock obtained from the Sierra Grande tails were clarified:

a) The concentration of P_2O_5 is sufficiently high.

b) The iron content in the phosphate rock is high and the quality of phosphate fertilizer obtained from it is not satisfactory, particularly in connection with the water solubility of phosphate in the fertilizer.

c) Most of the iron is ferrous from Fe (III).

d) Although the phosphate rock is finely ground, the reactivity with acids is very low.

e) The contents of organic matter and carbonates are low, and no foaming is observed during acid digestion with nitric and sulfuric acid.

The results of the evaluation of phosphate fertilizer production are summarized in below:

Phosphate Fertilizer Alternatives	Process Plant Configuration (Daily Capacity)	Process Applicability	Product Quality Evaluation
- Ground Phosphate Rock (GPR, 0-34-3)	PRC (340TPD) GPR (350TPD)	Applicable	Low in C-P_2O_5/T-P_2O_5 and F-P_2O_5/T-P_2O_5
- Fused Magnesium Phosphate (FMP, 0-21-0)	PRC (340TPD) FMP (570TPD)	Applicable (Open hearth furnace)	Excellent in C-P_2O_5/T-P_2O_5
- Single Super Phosphate (SSP, 0-20.5-0)	PRC (340TPD) H_2SO_4 (200TPD) SSP (572TPD)	Not applicable, Low reactivity, High H_2SO_4 consumption	Low in Av-P_2O_5/T-P_2O_5 and W-P_2O_5/T-P_2O_5, High in free acid
- Triple Super Phosphate (TSP, 0-47.3-0)	PRC (340TPD) H_2SO_4 (192TPD) P_2O_5 (82TPD) TSP (243TPD)	Not applicable, Low reactivity, High H_2SO_4 consumption	Low in Av-P_2O_5/T-P_2O_5 and W-P_2O_5/T-P_2O_5, High in free acid
- Wet Process Phosphoric Acid (P_2O_5, 0-100-0)	PRC (340TPD) H_2SO_4 (270TPD) P_2O_5 (115TPD)	Applicable, Limited in P_2O_5 concentration, Evolution of SO_3	High in viscosity and sludge formation, Concentration up to 40% of P_2O_5
- Ammonium Phosphate (MAP/DAP, 10-46-0)	PRC (340TPD) H_2SO_4 (270TPD) P_2O_5 (115TPD) MAP/DAP(244TPD)	Applicable, Fe is transferred in MAP/DAP	Slightly low in grade but satisfactory for domestic market, Low in Av-P_2O_5/T-P_2O_5, W-P_2O_5/T-P_2O_5 and W-N/T-N
- Nitrophosphate (NP, 20.8-20.8-0)	PRC (340TPD) NH_3 (303TPD) NA (534TPD) NP (551TPD) AN (360TPD)	Applicable, Fe is partially transferred in NP	Excellent in Av-P_2O_5/T-P_2O_5 and W-P_2O_5/T-P_2O_5

Note: PRC = Phosphate Rock Concentration, NA = Nitric Acid, AN = Ammonium Nitrate, F-P_2O_5 = Formic Acid Soluble P_2O_5, Phosphate fertilizer products are all in granular form and in bags.

6. Financial and Economic Viability

According to the comparative evaluation of the seven alternatives, the projects for the production of MAP/DAP and of NP were the most favorable.

In the case of MAP/DAP production, the financial and economic feasibility was not favorable due to the following reasons:

a) In spite of the high residual iron content in the phosphate rock, the production of phosphoric acid was proved to be technically feasible. However, the quality of the MAP/DAP product was a little lower than that of the traditional product.

b) The cost of ancillary raw materials such as sulfur and ammonia is comparatively high, due to the need of importing small lots from overseas or local production at a small scale plant. Although there are H_2SO_4 and NH_3 plants in Argentina, their production is committed and would not be available for the project.

c) The production capacity of phosphate rock (340 TPD) and of MAP/ DAP (244 TPD) are both small in scale due to the limited availability of tails at Sierra Grande; consequently, the fixed cost burden is higher in comparison with the world scale phosphate rock and phosphate fertilizer plants.

d) MAP/DAP production would cover only one half to third of the requirements of the local Argentine market.

In the second case, production of NP is technically viable, but its financial feasibility is low due to the low capacity utilization. The major reasons for this are the following:

e) The N/P_2O_5 ratio in NP is higher than that in fertilizers traditionally used in Argentina (mainly DAP); replacement would not proceed at a high rate.

f) Half of the N in NP and co-produced nitrogen fertilizer is nitrate nitrogen; replacement of traditionally used nitrogen fertilizers (urea and ammonium sulfate) would not proceed at a high rate.

g) The production capacity of the ammonia plant required for the project is 303 TPD. This scale is rather small; but if the already existing ammonia plant continues its operation, the combined nitrogen capacity would be larger than the slow-growing domestic market. The nitrogen fertilizer surplus would not be competitive in the export markets.

7. Present Status and Prospect

In 1985, following the feasibility study recommendations and taking into account the authorities' efforts to promote the increase of grain and cattle production through the use of fertilizers, new technical efforts have been undertaken for the recovery of P_2O_5 values from the Sierra Grande tails. Further, working group has been established with the participation of official agencies and research centers, aiming at the improvement of the

technical and economic aspects of the research and development of phosphate fertilizer production.

At present, the activity of the group is concentrated in three directions:

a) Optimization of the fertilizer product mix from the apatite concentrate with high Fe content.

b) Economic feasibility of production of fertilizers with low water-solubility but with high solubility in weak acids, for application to acidic soils and pastures.

c) Feasibility of application of new technologies; attack with gaseous SO_3, use of microbiology and others.

It is open to any proposal involving technology applicable to the economic production of phosphate fertilizer starting from a raw material having the specific characteristics of the phosphate rock from the tails of HIPASAM, Sierra Grande, Argentina.

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OPTIMISING RESOURCES FOR THE DEVELOPMENT OF INDIAN PHOSPHATE FERTILIZER INDUSTRY*

Prepared by

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SUMMARY

The fertilizer industry in India has come a long way. Presently there is an installed capacity of more than 5.8 mill. te N and 1.7 mill. te P_2O_5 in the country. The industry has made pioneering efforts in making use of indigenous phosphate rock. For meeting the growing needs of phosphatic fertilizers, a mixed strategy has been adopted. Because of very large dependence on imported raw materials, efforts to exploit the indigenous resources are being intensified. To ensure a fair return on investment, all fertilizers in India have been brought under statutory control. With proper policy support in terms of the end product, the objective of increased fertilizer production and consumption would be achieved.

I. Agriculture is the mainstay of the Indian economy and will continue to remain so. Fertiliser holds a key position in the system because of its accepted vital role in the growth of agricultural production. Since early 60s the Indian fertiliser scene has been continually expanding, embracing a whole range of fertiliser technology, using a wide spectrum of feedstock/raw materials and producing a vast array of products. The fertiliser industry occupies a pivotal position in the country. Presently India is the fourth largest producer and consumer of nitrogenous fertilisers and the sixth producer and consumer of phosphatic fertilisers in the world. The compound rate of growth in P205 capacity from 1960-61 to 1984-85 has been 10.9% per annum.

The build up in terms of P205 nutrient capacity over the years may be seen from Table I.

Table I: Growth in Phosphatic Fertiliser Capacity

Year	Straight Phosphatic -SSP/TSP		NP/NPK Complexes		Total	
	No. of plants	Cum. cap. '000 te P205	No. of plants	Cum. cap. '000 te P205	No. of plants	Cum. cap. '000 te P205
1950-51	9	86	-	-	9	86
1960-61	13	107	1	36	14	143
1970-71	27	232	5	214	32	446
1975-76	31	249	9	519	40	768
1980-81	44	538	10	810	54	1348
1984-85	59*	695	10	1027	69	1722

*Includes 16 small-scale SSP units having a total capacity of about 44,000 te P205

II. Mozaic of Product Pattern

Considering that both the principal inputs for phosphatic production, namely rockphosphate and sulphur had to be essentially imported and taking into account the compulsions to maximise foreign exchange savings during the early 60s, production of nitrophosphate was considered for minimising sulphur requirements and a nitrophosphate plant was set up at Trombay. Later in Trombay IV calcium nitrate freeze out method for furnishing nitrophosphate with 60% water-solubility was adopted. Another nitrophosphate plant,based on sulphate-recycle route has been set up at Haldia, which is being commissioned. Besides, single and triple superphosphate, phosphatic fertilisers are produced in the country in various grades of ammonium-phosphate, urea-phosphate and nitrophosphates. The production pattern of phosphatic fertilisers in various forms is shown in Table II.

Table II: Production Pattern

Fertiliser	1982-83	1983-84	1984-85
I. Straight Phosphatic			
1. SSP (16% P205)	211.2	238.7	303.6
2. TSP (46% P205)	10.8	9.7	4.6
3. Total straight Phosphatic	222.0	248.4	308.2
II. NP's			
(APS) 16-20-0	19.8	25.7	11.5
(APS) 20-20-0	25.3	40.3	79.5
(DAP) 18-46-0	212.0	332.5	411.8
(UAP) 24-24-0	3.1	1.0	1.2
(UAP) 28-28-0	68.4	75.5	74.9
(Nitro Phos) 20.7-20.7-0	47.8	55.5	55.6
Total NPs	376.4	530.5	634.5
III. NPK's			
(nitrophos) 15-15-15	36.9	40.6	41.2
14-35-14	15.4	2.7	10.2
19-19-19	26.6	29.8	22.3
17-17-17	99.2	84.0	97.8
10-26-26	24.2	28.2	53.3
12-32-16	177.3	97.4	141.8
14-28-14	5.7	2.5	8.9
Total NPK's	385.3	285.2	375.5
Grand Total I + II + III	983.7	1064.1	1318.2

III. Productivity in Phosphatic Industry

Considering the various odds and constraints under which Indian industry has to function,the performance of phosphatic plants,has been by and large satisfactory, barring a few plants. While the SSP industry and nitrophosphate plants have achieved an average capacity utilisation of around 75%, the performance of complex fertiliser plants based on imported phos-acid and ammonia

has been much more impressive with an average utilisation rate of about 100% during the last five years. The main reason for lower capacity utilisation of the P205 industry, except for the year 1984-85 in which it attained 89% utilisation, had been virtually the inoperative capacity of phos acid-TSP plants which constituted about 31% of domestic phos-acid capacity and 16% of the total P205 installed capacity. The performance of domestic phos-acid plants had been unsatisfactory because of problems of corrosion, rubber-lining, other critical equipment and inadequate availability of sulphuric acid for reaction.

The capacity utilisation in various segments of phosphatic industry is shown in Table III.

Table III: Percentage Capacity Utilisation

Year	Phos-acid (domestic production)	SSP	Nitrophos-phate	Complex plants (based on imported phos-acid)	Total P205 (all plants)
1980-81	64.3	65	76	108.5	65
81-82	56.8	71	75	95.0	69
82-83	61.2	74	70	98.8	69
83-84	53.1	72	80	95.0	70
84-85	61.6	74	81	120.3	89

IV. Resource Optimisation

An interesting feature in the development of fertiliser production in India is the optimisation and use of indigenously available feedstock and raw materials.

(A) Rockphosphate

The first large deposit of phosphate rock was discovered in Jhamar Kotra (Rajasthan) in 1969. The rockphosphate in the country is mainly confined to sedimentary rocks as phosphorite. Out of about 150 million te of indicated phosphate reserve in the country, around 122 mill te of rock having widely ranging P205 content from 10 - 32% P205 would require beneficiation. Mainly run of mine grade of +31% P205 containing silica 7-11% as impurity is directly used by the fertiliser industry. With the increasing Ore:over burden ratio, the production has been pegged at about 0.5 mill tpy. The reactivity compared to Jordan rock is poor and fineness above 90% through 100 mesh and acidulation with acid of 66-68% strength at 62-65°C and more retention time in the Den have to be maintained for SSP production. For phos-acid production a free SO3 level of 35-40 g/l and higher temp upto 70°C and higher solid content in the slurry helped in getting uniform rhombic shaped easily filterable crystals.

Jhamarkotra rock having apatite as the main phosphate bearing mineral and dolomite constituting the main gangue has been successfully subjected to beneficiation in a 200 tpd (input) semi-commercial plant upgrading the feed from 18-20% P205 to +32% P205 and MgO within 1.5%. The process involves bulk flotation of carbonate and phosphate at an alkaline pH and depress the silica

using a depressent followed by separation of high grade phosphate and carbonate at acidic pH. The experience will be utilised in optimising the process parameters for a commercial plant of 0.3-0.35 mill tpy concentrate capacity. Besides, a commercial beneficiation plant of 600 tpd to treat 20-25% P205 rock containing high silica from Maton deposits using froth flotation process is in operation since 1976. Currently about 0.7 mill te rock phosphate from domestic sources is usedin fertiliser production. Keeping in view the P205 content of the rock currently used in the phosphate industry and the grade of ore that can be subjected to beneficiation from the various deposits, the reserves could be broadly regrouped as:

i) Around 18 mill te of directly marketable grade having 30% P205 content and above of which about 17 mill te are in Udaipur(Rajasthan) and about one million te in Chattarpur & Sagar (M.P.).

ii) Around 32 mill te of rock containing 25-30% P205 (Rajasthan, M.P. & U.P.) may be considered as blendable grade. Small quantities of this grade is already being used after blending with high grade imported rock.

iii) Various grades of rock containing P205 upto 25% which would require beneficiation before use.

(B) Sulphur

Sulphur is abother basic raw material required in the phosphate fertiliser industry. India has no source of elemental sulphur and there is no production of sulphur, except a small quantity produced as by-product from petroleum refinery and that obtained from fuel oil gasification in fertiliser plants. But the country is endowed with huge reserves of pyrites at Amjhore(Bihar) and Saladipura (Rajasthan). The reserve at Amjhore is more than 300 mill te expressed as pyrite containing 40% S and in Saladipura the reserve has been estimated at 120 mill te of pyrite containing 20% S. Further the reserve of pyrite ferrous shale containing 10% S is about 1500 mill te. Two sulphuric acid plants (400 and 880 tpd) had been put up but the acid plants encountered technical problems due to impurity of pyrite feed and operation of these plants has since been stopped.

Sulphuric acid is also made in the country from sulphur bearing gases from zinc and copper Smelters. The six non-ferrous metal smelters have a cumulative capacity to produce 425,000 tpy of acid, however the production is limited to about 70,000 tpy of sulphur equivalent as acid.

V. Growth Strategy

The compound rate of growth in P205 consumption from 1960-61 to 1984-85 had been 15.6% per annum. The all-India ratio of N:P205 has been around 3.0. It is envisaged to achieve a ratio of about 2.5. Efforts are to be made to amend the imbalance and increase the consumption of P205. The planned capacity build up, estimated production, demand and gap in P205 up to the end of the decade are given in Table IV.

Table IV:Capacity Production and Demand Estimates of P205 ('000 te P205)

Year	Capacity	Production	Demand	Gap
1985-86	2013	1455	1955	(-)500
1986-87	2168	1625	2200	(-)575
1987-88	2733	1908	2353	(-)445
1988-89	2817	2109	2517	(-)408
1989-90	2891	2194	2687	(-)493

For meeting the growing needs of phosphatic fertilisers, mixed strategy has been adopted. The gap between the demand and indigenous production of P205 of around 0.5 million tonnes per annum will be met from imports. The indigenous capacity is based, partly on rockphosphate and sulphur and partly on imported phos-acid.

In order to meet the specific requirement of various crops with respect to essential secondary and micronutrients like sulphur, calcium, magnesium, copper etc,creation of substantial new capacity in the form of SSP has been undertaken. The SSP capacity would practically be doubled to 0.8 mill te P205 by 1989-90. To reduce country's dependence on imported sulphur, further production of nitrophosphate is also being considered. The total energy requirement for newer nitrophosphate processes is also claimed to be marginally less at 26.7 mill. KCal/te P205 as compared to 28.2 mill.KCal/te P205 based on ammonium-phosphate adopting sulphur route.

As a product DAP commands several advantages in manufacture, handling and storage. Very substantial expansion is planned in DAP capacity, mostly based on imported phos-acid at coastal locations to facilitate handling of imported phos-acid and ammonia. The % share of DAP in the total P205 capacity would increase to 38.5% by 1989-90. The planned expansion in the capacity of various phosphatic fertilisers is shown in Table V.

Table V: Expansion in capacity of various phosphatic fertilisers(P205)

Fertiliser	Grade	1984-85		1989-90	
		Capacity(in terms of P205) ('000 tonnes)	Percentage share of total	Capacity(in terms of P205) ('000 tonnes	Percentage share of total
1. SSP	16% P205	442.7	25.1	809.2	27.7
2. TSP	46% P205	252.2	14.6	252.2	8.6
3. Comb.Phosphates					
(a)Am.Phos. Sulphate	16-20-0 20-20-0	40.0	2.3	40.0	1.4
(b)Urea Amm. phos	28-28-0 14-35-14	104.0	6.0	104.0	3.6
(c)Nitro Phos	15-15-15 20.7-20.7-0	120.0	7.0	195.0	6.7
(d)Diammonium Phos	18-46-0	368.0	21.4	1130.0	38.5
(e)Other NP/NPKs		395.1	22.9	395.1	13.5
TOTAL		1722.0	100.0	2925.5	100.00

Efforts are also under way to increase the use of rockphosphate for direct application as phosphatic fertiliser. The fertility values of Mussoorie rock-phosphate has been found comparable with SSP in acidic and near normal soils. Presently about 80,000 te of rockphosphate containing 18-21% P205 is used for direct application in the country and it is planned to increase it to 120,000 te in the next 2 years. Phosphatic fertiliser production in the country would involve large dependence on imported raw materials (rockphosphate/sulphur) or intermediates (phos-acid). The estimated import requirements of rockphosphate, sulphur and phosphoric acid upto 1990 are given in Table VI.

Table VI: Import Requirements of Raw Materials & Phos-acid

('000 te)

Year	Rockphosphate	Sulphur	Phos-acid (P205)
1985-86	2660	875	650
1986-87	2835	890	900
1987-88	3055	945	1020
1988-89	3280	1035	1200
1989-90	3425	1075	1250

With sulphur demand growing out of pace with supply at the International level, the price of sulphur is likely to harden. Already in the recent past there has been a spurt in the sulphur prices to the extent of 50%. At the current price of sulphur, production of sulphuric acid from pyrites could be an economic proposition. Technology is claimed to be available for conversion of pyrites to elemental sulphur by the hydro-metallurgy and pyro-metallurgy route. The production of sulphuric acid/cement from phospho-gypsum, can also be considered. Established process technology is available and sulphuric acid production may be economically viable from phosphogypsum as compared with the increasing prices of imported sulphur. Recovery of sulphur as acid from SO2 bearing smelter gases from copper, lead and zinc smelters has also to be maximised.

Considering the large requirement of imported phos-acid it would be of advantage to tie-up supply of substantial quantities from firmed up sources on long-term basis. A beginning has already been made in the case of Senegal project where Indian companies have become equity partners in a phos-acid plant.

(VI) Tasks Ahead

A competent technological base has been progressively built up in the country in design, engineering, construction and operational management. Indigenous process technologies are available for acids, SSP/TSP and complex granulation plants. Latest technology like pipe reactor, pressure neutraliser and fluidised bed granulation etc are also being adopted. Auto-analyser for better quality control of various complex formulations have been widely adopted by the industry. Total

effluent recycle for pollution abatement is practiced in several plants. However, fluorine recovery and utilisation of byproduct gypsum requires attention.

Although a few plants have achieved above 100% capacity utilisation, nonetheless, productivity in several phosphatic plants needs improvement. The on-stream efficiency and capacity utilisation of phosphoric acid plants in particular have to be improved by revamping. Various retrofit schemes are to be implemented to further improve energy efficiency and productivity.

Forecast of world phosphatic fertiliser supply/demand balance indicates a comfortable availability of phosphatic fertilisers upto 1994-95 but a country of India's size and resources cannot be dependent for 100% of its requirements of raw materials for production of essential commodities like fertiliser, and therefore efforts to exploit the indigenous mineral resources have to be intensified. Sources for imported raw materials have to be diversified to the extent possible.

A target of 185 mill. te of food grain production has been kept for 1989-90 and to achieve this target the fertiliser consumption is aimed at 14 mill.te of nutrients. The balanced use of nitrogen, phosphate and potash along with micro-nutrients will assume greater importance. Out of total Indian nutrient consumption of about 47.5 kg/ha during 1984-85, the P_2O_5 consumption of 10.5 kg/ha is far below the desired levels. Suitable product pattern has to be evolved keeping in view the appropriate use of nutrients, depending upon soil and crop requirements.

The message of economic benefits of optimim fertilisation has to be spread much wider. A minimum cost-benefit ratio which will induce farmers to increase the use of fertilisers, has to be ensured. In addition to providing for incentives in the fertiliser pricing system, efficiency in fertiliser production and use, as well as fertiliser distribution will have to be considered. With proper policy support in terms of pricing of the end product, the objective of increased fertiliser production and consumption should certainly be achieved.